SOYBEAN OIL AS AN ALTERNATIVE TO SOLUBLE OIL IN MACHINING A MILD STEEL MATERIALS

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Abstract. This paper investigates the use of soybean oil as alternative cutting fluid to soluble oil in machining a mild steel material. Soybean oil and soluble oil (Standard) are used as cutting fluid when machining a mild steel material and their effect on the mild steel material was observed for 70 days. The results of the study shows that the use of soybean oil lead to a slight corrosion of the mild steel than that of the soluble oil used in the time past. The inability of soybean performance at 100% level to that of soluble oil may be due to racidity (decomposition) of soybean oil on the mild steel material, and the heat generated during machining. Although soybean shows a very high correlation (r) (0.782 and 0.730) on the rate of corrosiveness of the metal samples and looked more stable than soluble oil (fig.1) but still needs a further work. The result obtained by using chi-square (X^2) also confirmed the above assertion by having soybean (B_1) and soluble oil (S_1) as not significant and soybean (B_2) and soluble (S_2) as significant.

1. INTRODUCTION

The present economic recession in Nigeria, and the scarcity of soluble oil, necessitates the research into alternative raw materials as cutting fluids, which can be sourced locally. The need for a very high surface finish, high metal removal, total durability, and the safety of the machinists is desirable in a machine shop. This will eventually reduce machine breakdowns, wears and tears, and increase the life span of all industrial machineries, and the over dependence on important cutting fluids will be drastically reduced.

Cutting operations bring about considerable heat and friction, which are created by the plastic deformation of metal occurring on the shear zone when chip slides along the chip tool interface. This heat and friction cause metal to adhere to the cutting edge of the tool and the tool may break down. The result is a poor finish, hence the importance of a cutting fluid to reduce or dissipate away heat and make the surface of the material smooth.

The study of other local oil (palm oil and groundnut oil) has already been undertaken, to look at their suitability as lubricant for machining mild steel [1,2]. The result of the correlation (r) of palm oil 0.44 and 0.55 was very poor compared to that of groundnut oil of 0.772 and 0.842 respectively. Hence the essence of this paper is to attempt to look at soybean oil as a possible alternative to soluble, palm oil or groundnut oil in machining mild steel materials. It is however, to be noted that the research is still a continuous one, since more results are expected which will look at the rancidity of each oil and additives added to make the oils more acceptable.

2. LITERATURE REVIEW

Lubrication is the act of reducing the friction developed between two surfaces moving relatively to each other [1,2]. Lubrication can also be defined as a cooling system which conduct away from the cutting area, the heat that is inevitably generated and reduces the friction between the chip and tool face, and also the tool forces and power consumption [3]. According to [4]), cutting fluids are used to:

- conduct heat away from tool and work;
- reduce friction between chip and face of tool;
- improve surface finish;
- reduce energy requirements;
- extend the life of the cutting tool
- and to carry away swarf and chips from the cutting point.

A cutting soluble or lubricant should possess the following qualities [5]:

- it should be clear to allow an easy view of the work being tooled
- it should not be expensive
- it should not smell unpleasantly or go stale with age
- and it must be harmless to the operator

Soluble oils are mineral oil containing emulsifying agents, which enable them to be mixed with water and remain stable [6]. The oil is always added to the water and the ratio of mixture will depend on the work at hand. Heavy duty soluble oils containing EP (Extreme Pressure) additives are available with much improved lubricant properties.

Soybean (Glycline max) is essentially a sub-tropical crop but it also grows wild and it is wide spread in tropical Africa and Asia. It is now one of the world's most important legumes and a major

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source of edible oil and vegetable protein. Soybean occupy a premier position as a world crop because of its high and virtually unrivaled protein content and also because it is a rich source of edible vegetable oil. Spherical and yellow, though appearing black, brown and green soybeans exist. They are about 8% hull, 90% cotyledon and 2% hypocoty. Commercially yellow soybeans are graded on weight, moisture, percent splits, heat damage, contamination by foreign material and discoloration [7]. Although, soybean is a legume seed, with the possible exception of the winged bean, it is often classed as an oil-seed with oil content of 13-20%, which is often considered as low. Historically, in most producing countries outside the Orient it was originally processed largely for its edible oil. The high protein press cake or residue from solvent extraction process was mainly utilized as animal feed in form of a protein concentrate [8].

According to [9], soybeans have a high bulk density of about 770 kg/m^3 and they may be shipped relatively far from their growing area. There are three methods that can be used for the extraction of soybean oil; hydraulic press; screw press and solvent extraction [7]. The hydraulic press involves squeezing the oil seeds in a frame. The machine is simple but inefficient and it is no longer used for soybeans. Like hydraulic presses, screw presses are simple but they are relatively efficient and are suited to the conditions found in Africa. The industrial non-food uses of soybean oil are; paints, varnishes, resins and plastic, and recover from tools as oil, fatty acids and special synthetic rubber polyesters, polyamide resins and special cosmetics can be prepared from soybean oil. Other researchers [10-15] have all done a lot of work on the areas related to machining such as the,

- combination of new cutting tools and Computer Numerical Control (CNC), with high-speed spindles and rapid-traverse axis drives for faster feeds and speeds development
- development of spinning at more than 100,000rpm, high-speed spindles, for increase in material removal rates by five folds to boost productivity
- development of a technology that adopts rapid prototyping (RP) techniques and applies them to tool and die making instead of the traditional machining technique
- use of software, sensors, and controllers, which is a new generation of intelligent machine tools used for optimizing grinding, milling, and moudling processes
- development of the adaptive control system for rough turning, which control automatically two main turning parameters; feed and milling speed so as to optimize on line machining process
- development of automatic tool changing system and automatic set up, to reduce down time and provide flexibility for small and medium batch production
- requirements of tools when machining hard materials and the analysis of the specific forces, heat conductivity of the tool material were reduced.

All the above-enumerated researches failed to look at the areas of lubricating the machining processes, hence this paper is intended to fill the gap and possibly source for locally suitable lubricating oil for use.

3 MATERIALS AND METHOD

The machining and the experiments were carried out at the Federal University of Technology, Akure using the facilities at the engineering workshop for the machining aspect, and at the Refrigeration/Air-conditioning of the laboratory of the Department of Geological for the measurement and analysis. The work piece used throughout the test was a solid mild steel rod of initial dimension of 16mm diameter and 250mm long. The mild steel rod was turned down to 10mm diameter and part off to 50mm long. To maintain realistic values, the feed rate was at 114 revolutions per minute during turning on the centre lathe machine. The cutting tools used is high speed with 19mm shank. This was grounded to appropriate tool geometry using a tool and cutter grinder, the angle being maintained constant for each turning. Cutting fluid is applied to three areas namely;

- chip/tool interface;
- the area where plastic deformation and heat is taking place; and
- the chip.

It is to be observed that the reaction(s) taking place during machining lend itself to investigation [10,14,16], better than any other method of investigation, such as soaking the metal into the oil concerned, due to the mild steel ability;

- to expand or contract during machining; as witnessed in this research work;
- of the fluid used to dissipate away the heat generated and the plastic deformation taken place in the cutting zone;
- to produce a fine smooth surface with a bluish sheen, better than any other material;
- to be corrosive more quickly when exposed to atmospheric conditions, because of its carbon content and the heat it was already exposed to.

After turning with oil (soluble oil and soybean oil);

- the initial measurement of each sample (2 mild steel rod for soluble oil and 2 mild steel rod for soybean oil) was taken;

- the metal samples (mild steel) was left in an open place at room temperature for 70 days;
- the measurement of weight was taken for 70 consecutive days (Table 1);
- at the 70th day, the microstructure of the samples (mild steel) was taken and compared (Plates 1-4)

The analysis of the experiment was done in 3 ways;

Weight measurements:

i) measuring of weight for 70 days (Table 1);
ii) the calculation of weight for each sample (mild steel);

Viscosity of oil used

i) using viscometer; and
ii) calculating the viscosity using viscosity formulae.

Corrosion observation

i) calculation and the determination of the rate of corrosiveness (Fig. 1)
ii) microscopic observation (plates 1-4).

The mathematical analysis used to interpret the data is the simple statistical method of calculating mean, average etc, the method of least square regression, correlation, and the chi-square (X^2) methods. Conclusions are drawn from the data analysis using the above stated methods.

4. RESULTS AND DISCUSSIONS

The results are based on the effect of soybean oil on the machined mild steel material as an alternative to soluble oil due to the viscosity analysis, corrosiveness and the change in weight. The comparison was based on four samples of the machined mild steel materials. Two of the samples are machined using soybean oil and the other two are machined using the conventional soluble oil. The results are shown in Table 1, Fig.1 and Plates 1-4. The soybean oils are denoted B_1 and B_2, and soluble oil as S_1 and S_2.

The results obtained (Table 1) was analyzed to indicate the increase, decrease and the impermanent stability of the metals weight, due to the reactions of oxygen on the surface of the mild steel material to cause oxidation which in turn lead to corrosion of the metal.

4.1 Weight measurement-mathematical analysis

The mathematical analysis entails the various calculations which gave a clear result of the deterioration and corrosion of the machined mild steel material when soluble oil and soybean oil were used as lubricant on the four metal samples. It also shows increase and decrease in weight.

The weight of the mild steel using soluble oil (S_1 and S_2) and soybean (B_1 and B_2), shows that

- soluble oil S_1 has a total weight of 2072.15g and a mean of 29.60g for 70 days observation.
- soluble oil S_2 has a total weight of 2086.55g and a mean of 29.81g for 70 days observation.
- soybean oil B_1 has a total weight of 2200.35g and a mean of 31.43g for 70 days observation.
- soybean oil B_2 has a total weight of 1855.25g and a mean of 26.50g for 70 days observation.

It is however observed that there is an increase in the weight of the mild steel machined by soluble oil S_1 for 35 days and soluble oil S_2 for 11 days. Soybean shows a constant weight (4 days for soybean B_1 and 8 days for soybean B_2), and afterwards a constant decrease in weight. It can thus be concluded that;

- there is no expansion or increase in weight after the first day of machining of mild steel when using soybean oil (B_1 and B_2). This shows that soybean maintained a constant value or dimensions better than soluble oil, which is a great asset that can be exploited.
- there is an expansion or increase in weight after the first day of machining of mild steel when using soluble oil (S_1 and S_2), which may be due to heat gained during machining.

4.2 Viscosity Measurement (Viscometer)

The measurement and calculation related to the viscosity of the oil used has been undertaken. The soluble oil viscosity was determined using viscosity formula, which is 1.008, while that of the soybean oil viscosity is 40.853. The above results show that the viscosity of soybean is very high compared to that of soluble oil. There is need to further work on the viscosity and rancidity (decomposition) of soybean oil on the material machined. It was however observed that using soybean oil as a cutting fluid, dissipation of heat was not reduced, and rather it increased due to the high viscous nature of soybean oil. This leads to a thin layer when heated and which generated heat and smoke when used as a cutting fluid on the mild steel material during machining. Soluble oil on the other hand dissipates away heat and friction more rapidly and does not present any smoke during machining.

4.3 Corrosion Observation

Fig.1 shows the degree of corrosion relationship between each of the soybean oil (B_1 and B_2) and soluble oil (S_1 and S_2) used. Soybean shows better corrosive resistance property than soluble oil, which falls suddenly than soybean with a steady or little fall. The use of least square regression analysis was used for the evaluation of data obtained. The actual data from soybean oil and soluble oil observation (Table 1) was used to calculate the amount of corrosion of each of the metal samples and the determination of correlation (r) between the two samples and the corrosiveness was determined (Fig. 1).

- the total weight loss for soluble oil S_1 = -30.4g, while S_2 = -15.2g
- the total weight loss for soybean oil B_1 = -41.6g, while B_2 = -36.9g

The correlation (r) for this corrosiveness for soybean (B_1) and soluble oil (S_1) is 0.782, and that of soybean (B_2) and soluble oil (S_2) is 0.730. This indicate that the correlation (r) of soybean to soluble oil corrosiveness is very high and so soybean can be a good substitute to soluble oil for machining mild steel products, if further work is done on it. Statistically, soluble oil (S_1 and S_2) reacted better to atmospheric condition in terms of total weight loss or effect of its corrosiveness than soybean oil (B_1 and B_2).

Using Chi-Square (X^2) to test for statistical significance, that is, whether there is a significant level of association or relationship between the two variables (soluble oil and soybean oil) gives the following results;

- soluble oil (S_1) and soybean oil (B_1) has X^2 = 1.742, the rejection region used $X^2 > X^2_{0.05}$ from the table $n-1=1$, df gives 3.84. Since the computed $X^2 = 1.74$ is less than the critical value of 3.84, we conclude that at the α = 0.05 level of significance soybean oil can perform like soluble oil. Therefore, H_A for soybean oil is accepted and H_o for soybean oil is rejected i.e. not significant.
- soluble oil (S_2) and soybean oil (B_2) has $X^2 = 9.04$, the rejection region used $X^2 > X^2_{0.05}$ from the table $n-1=1$ df gives 3.84. Since the computed $X^2 = 9.04$ is more than the critical value of 3.84, we conclude at the α = 0.05 level of significance that soybean oil cannot perform like soluble oil. Therefore, H_A for soybean oil (B_2) is rejected and H_o for soybean oil is accepted i.e. not significant.

It is to be noted that the same result of significance was attained if the weight in Table 1 is computed. When the soluble oil (S_1 and S_2) and soybean (B_1 and B_2) was computed it has for soluble oil $X^2 = 12.8$, the rejection region used $X^2 > X^2_{0.05}$ from the table $n-1=3df$, which gives 7.81. Since the computed $X^2 = 12.8$ which is higher than the critical value of 7.81, we conclude that at the $\alpha = 0.05$ level of significance

- soybean oil cannot perform like soluble oil. Therefore, H_A soybean oil is rejected and H_o is accepted i.e. significant.

Note the hypothesis used that:

H_o = Soybean oil does not perform like soluble oil

H_A = Soybean oil can perform like soluble oil

Plates 1-4 shows the grain structure where the effect of the corrosion can actually be seen after exposing it to the atmosphere at room temperature for 70 days, the photograph were taken using powerful microscope. It clearly shows the relationship between the two oils that soluble oil is still better than soybean oil. It should be observed that the two soybean oils (B_1 and B_2) produced darker grain structure than that of the soluble oil (S_1 and S_2). There are still some grain structures yet to be corrosive in the soluble oil (S_1 and S_2) than that of soybean oil (B_1 and B_2). Hence the decision that soybean oil (B_1 and B_2) need to be further worked upon to make it a 100% suitable alternative oil to soluble oil for machining mild steel material.

Table 1: Weight of the mild steel using soybean (B) and Soluble oil (S). in grams

Number of days	S_1	B_1	S_2	B_2
1	30.00	32.00	30.00	27.00
2	30.40	32.00	30.30	27.00
3	30.20	32.00	30.30	27.00
4	30.20	32.00	30.20	27.00
5	30.40	31.50	30.20	27.00
6	30.40	31.50	30.20	27.00
7	30.40	31.50	30.20	27.00
8	30.40	31.50	30.20	27.00
9	30.40	31.50	30.20	26.50
10	30.30	31.50	30.20	26.50
11	30.30	31.50	30.20	26.50
12	30.30	31.50	30.00	26.50
13	30.30	31.50	30.00	26.50
14	30.30	31.50	30.00	26.50
15	30.30	31.50	30.00	26.50
16	30.30	31.50	30.00	26.50
17	30.30	31.50	30.00	26.50
18	30.30	31.50	30.00	26.50
19	30.30	31.50	30.00	26.50
20	30.30	31.50	30.00	26.50
21	30.30	31.50	30.00	26.45
22	30.30	31.50	30.00	26.45
23	30.30	31.50	30.00	26.45
24	30.30	31.50	30.00	26.45
25	30.20	31.50	30.00	26.45
26	30.20	31.50	30.00	26.45
27	30.20	31.50	30.00	26.45
28	30.20	31.50	30.00	26.45
29	30.20	31.50	30.00	26.45
30	30.20	31.50	30.00	26.45
31	30.20	31.50	30.00	26.45
32	30.20	31.50	29.80	26.45
33	30.20	31.50	29.80	26.45
34	30.10	31.50	29.80	26.45
35	30.10	31.50	29.80	26.40
36	29.00	31.50	29.70	26.40
37	29.00	31.40	29.70	26.40
38	29.00	31.40	29.80	26.40
39	29.00	31.40	29.80	26.40
40	29.00	31.30	29.80	26.40
41	29.00	31.30	29.80	26.40
42	29.00	31.30	29.80	26.40
43	29.00	31.30	29.60	26.40
45	29.00	31.30	29.60	26.40
46	29.00	31.30	29.60	26.40
47	29.00	31.30	29.60	26.40
48	29.00	31.30	29.60	26.40
49	29.00	31.30	29.60	26.40
50	29.00	31.20	29.40	26.40
51	28.80	31.20	29.40	26.40
52	28.80	31.20	29.40	26.40
53	28.80	31.20	29.40	26.40
54	28.80	31.20	29.40	26.40
55	28.80	31.20	29.40	26.30
56	28.80	31.20	29.40	26.30
57	28.80	31.20	29.40	26.30
58	28.80	31.20	29.40	26.30
59	28.80	31.20	29.40	26.30
60	28.80	31.20	29.40	26.30
61	28.80	31.20	29.40	26.30
62	28.80	31.20	29.40	26.30
63	28.80	31.20	29.40	26.30
64	28.80	31.20	29.40	26.30
65	28.80	31.20	29.40	26.30
67	28.80	31.20	29.40	26.30
68	28.80	31.20	29.40	26.30
69	28.80	31.20	29.40	26.30
70	28.80	31.20	29.40	26.30

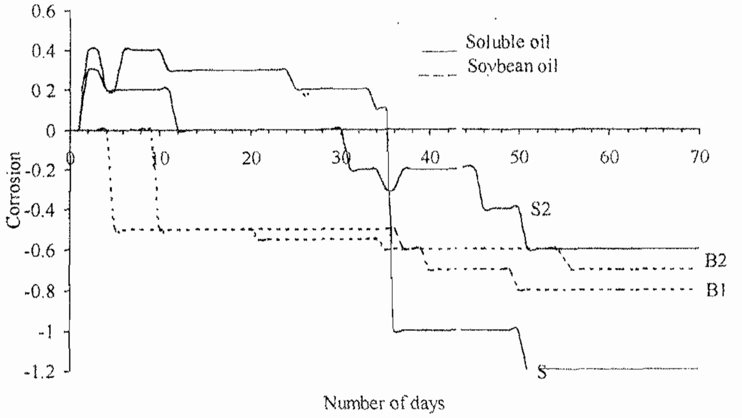

Fig.1 Comparison of the rate of corrosion between soybean oils (B_1, B_2) and soluble oils (S_1, S_2).

Plate 1: Soluble oil S_1

Plate 3: Soybean oil B_1

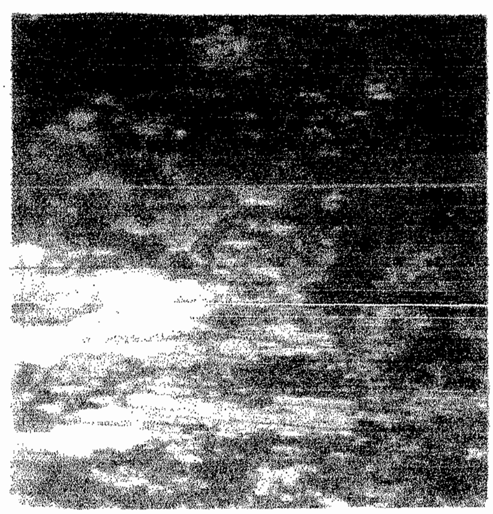

Plate 2: Soluble oil S_2

Plate 4: Soybean oil B_2

5. CONCLUSION

Soybean oil has been presented as alternative soluble oil in machining a mild steel material. From the analysis of the experiment, it was observed that:

i) Soybean can be a good substitute to soluble oil for machining mild steel material if further work is done on its viscosity and rancidity (decomposition) on the material (mild steel materials) during machining,

ii) The corrosiveness of the metal samples for soybean (B_1 and B_2) presented a good comparison with that of soluble oil (S_1 and S_2) in both mathematical calculations and in Fig.1, although the total corrosiveness measured in soybean (B_1 and B_2) is higher than that of soluble oil (S_1 and S_2).

iii) As regards the weight of the materials, it was deduced from the mathematical calculation, that soybean oil (B_1) was higher than any of the oil used, followed by the two soluble oil (S_1 and S_2), and soybean (B_2) was the least.

iv) The correlation (r) for the corrosion between the performance of soybean oil and soluble oil as lubricant was found to be high.

v) The result of the chi-square (X^2) hypothesis to test for statistical significance shows that more work need to be done on soybean to make it H_A (Soybean can perform like soluble oil) so as to make it not significant, since the present result shows that it is H_o significant.

Therefore, from the foregoing, soybean oil still need further work in the area of rancidity (decomposition) before it can be made a perfect lubricating oil in machining mild steel or other carbon materials.

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